

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: Field X-Ray Fluorescence Measurement

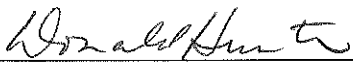
Effective Date: November 1, 2007

Number: SESDPROC-107-R1

Authors

Name: Donald Hunter


Title: Environmental Scientist, Regional Expert

Signature:  **Date:** 11/02/07

Approvals

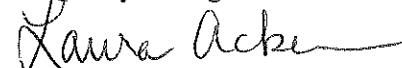
Name: Antonio Quinones

Title: ~~Chief, Enforcement and Investigations Branch~~

Signature:  **Date:** 11/02/07

Name: Laura Ackerman

Title: Field Quality Manager, Science and Ecosystem Support Division

Signature:  **Date:** 11/02/07

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Quality Manager.

History	Effective Date
<p>SESDPROC-107-R1, <i>Field X-Ray Fluorescence Measurement</i>, replaces SESDPROC-107-R0</p> <p>General Updated referenced procedures due to changes in title names and/or to reflect most recent version.</p> <p>Title Page Changed title for Antonio Quinones from Environmental Investigations Branch to Enforcement and Investigations Branch.</p> <p>Section 1.3 Updated information to reflect that procedure is located on the H: drive of the LAN.</p> <p>Section 1.4 Alphabetized and revised the referencing style for consistency.</p> <p>Section 2 Added last paragraph regarding stopping measurements due to environmental conditions.</p>	November 1, 2007
SESDPROC-107-R0, <i>Field X-Ray Fluorescence</i> , Original Issue	February 05, 2007

TABLE OF CONTENTS

1	General Information.....	4
1.1	Purpose.....	4
1.2	Scope/Application	4
1.3	Documentation/Verification.....	4
1.4	References.....	4
1.5	General Precautions.....	5
1.5.1	<i>Safety</i>	5
1.5.2	<i>Procedural Precautions</i>	5
1.5.3	<i>Limitations</i>	6
2	Operational Checks and Quality Control.....	8
3	Field X-Ray Fluorescence (XRF) Measurement Procedures.....	8
3.1	General.....	9
3.2	Mode of Operation.....	9
3.2.1	<i>In Situ Measurement</i>	9
3.2.2	<i>Cup Measurement</i>	10
4	Study Design.....	11
4.1	General.....	11
4.2	Reconnaissance.....	11
4.3	Screening Support for Definitive Level Site Characterization	11

Contents

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when conducting field X-ray fluorescence (XRF) measurements of soil and sediment samples.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when measuring metals concentrations in soil, sediment or other solids in the field. On the occasion that SESD field personnel determine that any of the procedures described in this section cannot be used to obtain metals analyses of the media being sampled, and that another method or XRF instrument must be used to obtain said measurements, the variant instrument and measurement procedure will be documented in the field log book, along with a description of the circumstances requiring its use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the H: drive of the SESD local area network. The Field Quality Manager is responsible for ensuring the most recent version of the procedure is placed on the H: drive and for maintaining records of review conducted prior to its issuance.

1.4 References

Integrated Laboratory Systems, Inc. Standard Operating Procedure, Analysis for Metals in Soil Using the NITON 700 Series Multi-element XRF Spectrum Analyzer

Integrated Laboratory Systems, Inc. Standard Operating Procedure, Analysis for Metals in Soil Using the NITON Xli 700 Series Multi-element XRF Spectrum Analyzer

SESD Operating Procedure for Equipment Inventory and Management, SESDPROC-108, Most Recent Version

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version

SESD Operating Procedure for Sediment Sampling, SESDPROC-200, Most Recent Version

United States Environmental Protection Agency (US EPA). 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Region 4 Science and Ecosystem Support Division (SESD), Athens, GA

US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when conducting field XRF measurements. Refer to the SESD Safety, Health and Environmental Management Program Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASPs) for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional. When using this procedure, minimize exposure to potential health hazards through the use of protective clothing, eye wear and gloves. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate.

Additional safety requirements include:

- Analysts performing NITON XRF analyses are included in the Region 4 SESD Radiation Monitoring Program. The analyst must wear the assigned radiation monitoring badge/device when using the NITON or other XRF instrument.
- The NITON XRF units, both the 700 Series and the XLi 700 series Multi-Element XRF Spectrum Analyzers contain sealed isotopic x-ray sources with safety locks to prevent the shutter to the x-ray sources from accidentally opening. The operator should always be aware of the instrument's radioactive source and the direction of its beam of x-rays. The operator should never point the open source at anyone.

1.5.2 Procedural Precautions

All field XRF measurements pertinent to the sampling event are recorded in a bound field record log book for the event. This record is created and maintained by the ILS analyst providing the field XRF support. After the investigation is complete, the ILS analyst will conduct post-processing of the field measurements and will enter final measurement data in the SESD laboratory information management system and provide the SESD project leader with a copy of the field measurement log book. All other records and documentation of the investigation

should be recorded according to the procedures outlined in the SESD Operating Procedure for Logbooks (SESDPROC-010).

1.5.3 Limitations

There are three main sources of inference in XRF analysis that may impact data quality. They are sample preparation error, spectral interferences and chemical matrix interferences.

- Preparation Error - The accuracy of the analysis is strongly impacted by sample homogenization. The more homogeneous the sample, typically analyzed by the cup method, the more accurate the results. There is no control of this limitation when conducting in situ analysis.
- Spectral Interference – Each element has a signature spectrum of energies and relative intensities. Many elements, however, produce x-rays of similar energy and discerning which element produced a detected x-ray is a factor of the detector's resolution capability and the software's ability to fit all of the data to the relative intensities produced by the various wavelengths.
- Chemical Matrix Interference – This refers to the effect that one element has on another in producing x-rays which reach the detector. Dominant elemental components of a sample, such as silicon in soils, vary in concentration from sample to sample and therefore so does that element's influence on the other elements in the sample.

There are several other limitations that the field investigator must be acutely aware of when conducting field analysis using XRF.

- Soil moisture – Excessive soil moisture biases the results low, i.e., the higher the soil moisture in a particular matrix, the lower the reported concentration relative to the actual concentration. This limitation may be overcome by drying the sample, either in a microwave oven or a standard laboratory oven. Without sample drying, XRF measurement results for samples with typical soil moistures within the range of 15% - 25% are routinely reported at values less than laboratory confirmation analysis for the same samples. The actual difference may vary significantly for all samples from a site but the XRF results reported by the instrument are typically on the order of 70% - 80% of the laboratory reported value for samples in this moisture range. This factor should be taken into consideration when making decisions based on XRF results.
- Lack of sensitivity with respect to certain analytes – Due to peak overlaps, some analytes may have problematically high detection limits, i.e.,

detection limits may be higher than project action levels for certain analytes, limiting its use for rapid field screening for certain elements. One of the most common examples of this phenomenon is the lead/arsenic analyte pair. When lead and arsenic are being analyzed, the peak overlap problem results in detection limits for arsenic that are several times higher than the typical action levels published for this analyte. It commonly is necessary to perform confirmatory analysis in the laboratory to obtain analytical results for arsenic, or other analytes with high detection limits, to obtain data in the range necessary for making regulatory decisions.

2 Operational Checks and Quality Control

All XRF instruments shall be maintained and operated in accordance with the manufacturer's instructions, the standard operating procedures for each instrument and the SESD Operating Procedure for Equipment Inventory and Management (SESDPROC-108). In the field, prior to each use, each instrument is subjected to an internal instrument calibration. Following this calibration, National Institute of Standards and Technology (NIST)-traceable standard reference materials for the analytes of concern, preferably within the anticipated range of concentrations for these constituents, are analyzed and recorded. Following this performance check, an instrument blank sample is analyzed to verify the instrument is not registering false positive results for the analytes of concern. After these checks, the instrument is ready for analysis.

The following operational and quality control requirements also apply to operation of the XRF instrument and must be followed and documented in the field record maintained by the ILS analyst:

- If, during operations, the ambient air temperature changes by more than 10°F since the last calibration, the instrument must be recalibrated.
- A method blank is analyzed at least once a day to determine if contamination is entering the analytical procedure.
- While the instrument is being used, the reference standards and the blank are run once each hour or every twenty samples, whichever occurs first, and also at the end of the period of operation, prior to turning the instrument off.
- For every twenty samples, or at least once per day, analyze a duplicate using the main sampling technique.
- Once per day, check the instrument's precision by analyzing one of the site samples at least seven times in replicate.

The referenced method documents for both instruments, found in Section 1.4 of this document, contain detailed instruction and guidance covering implementation of these procedures and any corrective actions that must be taken based on measured instrument behavior and performance. All data for the field verifications and instrument checks should be documented, along with the actual sample analytical data, in the logbook maintained by the analyst.

If at any time during a field investigation, it appears that the environmental conditions could jeopardize the quality of the measurement results, the measurements will be stopped. This will be documented in the field logbook.

3 Field X-Ray Fluorescence (XRF) Measurement Procedures

3.1 General

X-Ray Fluorescence (XRF) is the property of a material to emit x-rays, with a characteristic energy, upon being irradiated by x-rays from a known radioisotope source. The emitted x-rays are detected by the particular XRF instrument as they impact a detector, which converts the energy of the emitted x-ray into electric current. The strength of the current is proportional to the energy of the x-ray. An onboard microprocessor counts how often an energy is detected, assigns the energy to a particular element and reports the calculated concentration for the element.

There are two different XRF instruments available for use by SESD field investigators:

- Niton® 700 Series Multi-element XRF Spectrum Analyzer
- Niton® XLi 700 Series Multi-element XRF Spectrum Analyzer

The primary difference between the two XRF instruments is the radioactive isotope source used by each. The Niton® 700 Series uses a Cadmium¹⁰⁹ source, which has a short half-life and has to be periodically re-sourced. The Niton® XLi 700 Series instrument uses an Americium²⁴¹ source whose half-life is significantly long enough that the unit never needs to be resourced.

3.2 Mode of Operation

The XRF instruments are typically used in one of two modes, either for taking in situ measurements or for measuring sample material that has been placed in a cup for analysis in the instrument tray. The following is a brief description of these modes of operation.

3.2.1 *In Situ Measurement*

Prior to taking the in situ measurement, the measurement location is cleared of any significant vegetation, such as large clumps of grass, and is scuffed or otherwise leveled to provide a flat surface on which to place the instrument window. A piece of thin Mylar® film is then placed on the measurement location. This protects the instrument window, preventing it from becoming damaged or contaminated by the media being tested. After the window is pressed to the Mylar® film, the window is opened for a nominal sixty seconds. For the Americium-sourced Niton® XLi 700 unit, this equates to approximately sixty seconds. The measurement time for the Cadmium-sourced Niton® 700 unit will typically be in excess of sixty seconds, however, and this time will increase over time, due to the radioactive decay of the source. The method manual provides instructions for taking this decay into account to determine the length of time the window must remain open.

Because of the shallow penetration of the X-rays in typical soils, the measured concentrations are representative of the concentrations present at the very surface

of the material being measured. If conditions representing concentrations over a greater depth are required by the study data quality objectives (i.e., on the order of three- to six-inches), the cup method, described in Section 3.2.2, must be used.

3.2.2 Cup Measurement

The cup method is used to measure concentrations of metals in soil and sediment samples collected over a vertical interval. Typically, soil or sediment samples are collected as if the samples were being collected for routine chemical analyses (SESD Operating Procedure for Soil Sampling (SESDPROC-300) and SEDS Operating Procedure for Sediment Sampling (SESDPROC-200). After mixing, the media being sampled may be placed in either an 8-ounce glass container or a clean, unused zip-closure plastic bag. The XRF analyst then takes an aliquot from the container and places it in a small plastic cup with a Mylar covering. The cup containing the sample is then loaded into a tray for analysis by the XRF instrument. Window opening time considerations are the same as for the in situ measurement procedures described in Section 3.2.1.

The concentrations reported for the samples analyzed by the cup method are representative of the interval sampled, i.e., if the sampler collected the sample from the interval of 0 inches to 3 inches below ground surface, the reported concentration, assuming thorough homogenization, will be an average of the concentrations over that interval.

4 Study Design

4.1 General

XRF instruments may be used to either rapidly assess site conditions to support a site reconnaissance or they may be used to screen large numbers of soil or sediment samples to minimize the number of samples that are sent to a laboratory to provide detailed site characterization data. These uses are summarized in the following sections.

4.2 Reconnaissance

XRF may be used to obtain in situ measurements at a large number of locations in a short period of time to determine if a site warrants further attention with respect to characterization. When used in concert with GPS, and when observing the limitations described in Section 1.5.3, XRF can reveal, where present, contamination patterns at a site which can form the basis for development of a more detailed study to provide definitive level data for site characterization. Conversely, the reconnaissance results may form the basis for a “no further action” decision, providing a very cost effective tool for the decision maker.

4.3 Screening Support for Definitive Level Site Characterization

XRF may be used to supplement laboratory analyses to allow for the collection of large numbers of samples to provide a detailed characterization of a site. A high sample density grid or sampling pattern is created to provide adequate detail to meet the data quality objectives of the study or investigation. This sampling pattern may also involve the collection of significant numbers of subsurface soil samples to characterize any contamination present in the subsurface.

All samples, collected according to procedures found in SESD Operating Procedure for Soil Sampling (SESDPROC-300) and SESD Operating Procedure for Sediment Sampling (SESDPROC-200), are delivered to the XRF analyst on site for rapid screening. The XRF analysis of these samples is conducted using the cup method described in Section 3.2.2 of this procedure.

Based on the limiting factors described in Section 1.5.3, a confirmatory analytical scheme can be developed which minimizes the numbers of samples that must undergo laboratory analyses, yet provides definitive level data, with a high degree of confidence, to the project leader and other decision makers. Using the moisture limiting factor, there is usually a high degree of confidence that samples that screen at concentrations less than approximately 70% - 80% of the site action level will actually exceed the action level. Of the samples that screen *at* the action level, most all, with a high degree of confidence will exceed the action level. If a reconnaissance is conducted prior to the full-scale site investigation, it is advisable to analyze a small subset of the screened locations in the laboratory to generate site-specific moisture limiting factors, i.e., compare the in situ

reconnaissance concentrations to laboratory numbers to determine the correlation factor between XRF and laboratory results. This correlation factor can be used to develop a sampling scheme with more confidence.

Using these relationships, the following scheme may be implemented:

- Ten percent of the samples that screen at concentrations less than approximately 70% - 80% (or other correlation factor developed on actual data) of the site action levels are submitted for confirmation analyses to confirm that concentrations are, in fact, below the site action levels.
- All of the samples that screen at concentrations of 70% - 80% (or other correlation factor developed on actual data) of the action level up to the action level value are submitted for confirmation analyses to confirm that concentrations are, in fact, equal to or greater than the site action levels.
- Ten percent of the samples that screen at concentrations exceeding the action levels are submitted for confirmation analyses to confirm that concentrations are, in fact, greater than the site action levels.